

A Comparison of Critical Thinking Skills Across Group and Pair Work: A PLS-SEM Analysis

Siti Nurul 'Ain hj Zaiton¹, Noor Hanim Rahmat^{2*}, Zahari Abu Bakar³, Ahmad Khudzairi Khalid⁴,
Millaa-Armilla binti Asli⁵, Rahayu Izwani Borhanuddin⁶, Lidya Ayuni Putri⁷

¹Faculty of Science, Universiti Teknologi MARA Johor Branch, Pasir Gudang Campus, 81750 Masai, Johor, Malaysia

^{*2}Akademi Pengajian Bahasa, Universiti Teknologi MARA, Shah Alam, Malaysia

³Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Johor Kampus Pasir Gudang, 81750 Masai Johor, Malaysia

⁴Faculty of Computer Science and Mathematics, Universiti Teknologi MARA Cawangan Johor Kampus Pasir Gudang, 81750 Masai Johor, Malaysia

⁵Faculty of Applied Sciences, Universiti Teknologi MARA Cawangan Sarawak, Kampus Kota Samarahan Sarawak

⁶Fakulti of Accountancy, Universiti Teknologi MARA Johor Branch, Pasir Gudang Campus, 81750 Masai, Johor, Malaysia

⁷Department of Management, University of Lampung, Jln. Prof. Soemantri Brojonegoro no. 1, rajabasa, Bandar Lampung, lampung, Indonesia, 35145

***Corresponding Author**

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ABSTRACT

This study investigates the comparison of critical thinking skills across group work and pair work using a Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis framework. Grounded in Social Constructivism Theory by Vygotsky (1978), Collaborative Learning Theory by Bruffee (1999), and Experiential Learning Theory by Kolb (2015), the study examines how collaborative interactions contribute to the development of critical thinking skills. A quantitative research design was employed involving 232 respondents from higher education institutions. Data were collected using a questionnaire adapted from Belbin (2014), Bateman et al. (2002), and Baleghizadeh and Farhesh (2014), which measured critical thinking through thought-oriented, action-oriented, and people-oriented dimensions, as well as group work and pair work interaction factors. The data were analyzed using SmartPLS 4 through measurement and structural model assessments. The findings revealed that group work had significant relationships with thought-oriented, action-oriented, and people-oriented critical thinking skills, while pair work showed a significant relationship only with thought-oriented skills. In addition, group work demonstrated stronger effects on critical thinking development compared to pair work. These findings support previous studies highlighting the effectiveness of collaborative learning in enhancing critical thinking, teamwork, and communication skills. The study implies that structured collaborative learning activities, particularly group work, should be integrated into educational practices to strengthen higher-order thinking skills. Future research is recommended to include broader samples and additional variables to further examine the relationship between collaborative learning and critical thinking development.

Keywords: critical thinking, group work, pair work, collaborative learning, PLS-SEM analysis

INTRODUCTION

Background of Study

Critical thinking has become one of the most essential skills in modern education because it enables students to analyze information, solve problems, and make reasoned decisions in academic and professional settings. Recent educational studies have emphasized the importance of collaborative learning approaches, particularly group work and pair work, in developing critical thinking skills. highlighted that Project-Based Learning (PBL) significantly improved students' critical thinking, teamwork, and communication skills through collaborative activities. Similarly, Silva et al. (2022) found that cooperative learning methods such as Think-Pair-Share and Roundtable were more effective than traditional teaching approaches in enhancing observation, interpretation, inference-making, and argumentation skills. These studies suggest that interaction and collaboration play an important role in promoting higher-order thinking. In addition, Gayle & Roque (2024) reported that both individual and group activities contribute to critical thinking development, with group work encouraging collaborative problem-solving, perspective-taking, and knowledge-sharing.

Despite the growing interest in collaborative learning, several issues remain unresolved regarding how different interaction types influence critical thinking development. Group work often promotes discussion and exposure to multiple perspectives, but challenges such as unequal participation and difficulty maintaining cognitive depth during discussions have been reported. (Fan et al., 2025) .Further observed that larger collaborative groups improved collective critical thinking but also created conflicts and reduced favorable perceptions toward collaborative tasks. On the other hand, pair work provides more focused interaction and immediate feedback, which may support deeper reflection and equitable participation. (Shaharuddin et al., 2026) found that both pair work and group work positively influenced critical thinking skills, although the level of engagement differed according to interaction type. However, current research still lacks a clear comparison of how group work and pair work specifically contribute to critical thinking in naturalistic learning settings. Furthermore, limited studies have applied a PLS-SEM approach to examine the structural relationships between collaborative interaction factors and critical thinking skills. Therefore, this study seeks to address this research gap by comparing critical thinking skills across group work and pair work using a PLS-SEM analysis framework.

Research Objective, Research Questions, and Hypothesis

The research questions will be answered using SmartPLS analysis using both measurement and structural models.

Table 1- Distribution of Research Objective, Questions & Hypotheses

RO	RQ	RESEARCH HYPOTHESIS
To investigate if there is a significant relationship between Group work and Thought-Oriented Skills	Is there a significant relationship between Group work and Thought-Oriented Skills?	Ho1: There is no significant relationship between Group work and Thought-Oriented Skills
To investigate if there is a significant relationship between Group Work and Action-Oriented Skills	Is there a significant relationship between Group Work and Action-Oriented Skills?	Ho2: There is no significant relationship between Group Work and Action-Oriented Skills
To investigate if there is a significant relationship between Group Work and People-Oriented Skills	Is there a significant relationship between Group Work and People-Oriented Skills?	Ho3: There is no significant relationship between Group Work and People-Oriented Skills
To investigate if there is a significant relationship between Pair work and Thought-Oriented Skills	Is there a significant relationship between Pair work and Thought-Oriented Skills?	Ho4: There is no significant relationship between Pair work and Thought-Oriented Skills

To investigate if there is a significant relationship between Pair Work and Action-Oriented Skills	Is there significant effect between Pair Work and Action-Oriented Skills	Ho5: There is no significant between Pair Work and Action-Oriented Skills
To investigate if there is a significant relationship between Pair Work and People-Oriented Skills	Is there a significant relationship between Pair Work and People-Oriented Skills	Ho6: There is no significant between Pair Work and People-Oriented Skills
To investigate if there is a significant effect between Group Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Is there is a significant effect between Group Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Ho7: There is no significant effect between Group Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)
To investigate if there is a significant effect between Pair Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Is there is a significant effect between Pair Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Ho8: There is no significant effect between Pair Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)

LITERATURE REVIEW

Theoretical Framework

Social Constructivism

Social Constructivism, proposed by (Vygotsky, 1978) posits that learning occurs through social interaction and collaboration with others. According to this theory, knowledge is constructed through communication, shared experiences, and active participation in meaningful tasks. Vygotsky emphasized the concept of the Zone of Proximal Development (ZPD), which refers to the gap between what learners can accomplish independently and what they can achieve with guidance or collaboration from peers and teachers. In group interactions, students are exposed to different perspectives, ideas, and problem-solving approaches, which encourage them to question assumptions, justify opinions, and evaluate arguments critically. Through discussion and cooperative activities, learners develop higher-order thinking skills such as analysis, interpretation, and reasoning. Group work also allows students to scaffold each other's learning by providing feedback, clarification, and support during tasks. This interaction helps learners move beyond simple memorization toward deeper understanding and reflective thinking. Therefore, Social Constructivism strongly supports the use of collaborative learning environments because group interactions create opportunities for students to actively construct knowledge and strengthen critical thinking skills through meaningful social engagement.

Collaborative Learning Theory

Collaborative Learning Theory (Bruffee, 1999) emphasizes that learning is a social process in which knowledge is constructed through interaction, discussion, and cooperation among learners. The theory argues that students develop understanding more effectively when they work together to exchange ideas, negotiate meaning, and solve problems collectively rather than learning individually. In collaborative group settings, students are encouraged to explain their opinions, defend arguments, question assumptions, and evaluate alternative viewpoints. These interactions stimulate deeper thinking and promote the development of critical thinking skills. Group work also exposes learners to diverse perspectives, allowing them to analyze issues from multiple angles and refine their reasoning through dialogue and feedback. According to Bruffee, collaborative learning shifts the classroom from a teacher-centered environment to a student-centered community where learners actively participate in knowledge construction. Through group discussions and shared problem-solving activities, students become more reflective, analytical, and independent thinkers. Therefore, Collaborative Learning Theory strongly supports the use of group work because meaningful interaction and cooperation among peers

create opportunities for learners to strengthen critical thinking, communication, and problem-solving abilities simultaneously.

Experiential Learning Theory

Experiential Learning Theory (Kolb, 2015) explains that learning occurs through experience, reflection, and active engagement in meaningful tasks. According to Kolb, learners develop knowledge through a continuous cycle consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. This theory emphasizes that students learn more effectively when they are directly involved in activities that require them to think, reflect, and apply knowledge in practical situations. In pair work, Experiential Learning Theory is highly beneficial because students actively interact with one another while completing tasks, discussing ideas, and solving problems together. Through these interactions, learners can reflect on their experiences, exchange feedback, and refine their understanding collaboratively. Pair work also creates a supportive learning environment where students feel more comfortable expressing opinions, asking questions, and testing new ideas. This close interaction encourages deeper engagement and promotes critical thinking as learners analyze information, justify their reasoning, and evaluate alternative perspectives. Furthermore, pair work allows immediate peer feedback, which helps students identify weaknesses in their thinking and improve problem-solving strategies. Therefore, Kolb's Experiential Learning Theory supports pair work as an effective approach for developing critical thinking, communication, and reflective learning skills.

Past Studies on Critical Thinking, Group Work, and Pair Work

Past studies have consistently emphasized the importance of collaborative learning in promoting critical thinking skills. (Dias-Oliveira et al., 2024) examined a Project-Based Learning (PBL) approach among first-year business students and found that group-based activities significantly improved students' critical thinking, teamwork, and communication skills. Similarly, (Gayle & Roque, 2024) investigated the effects of individual and group activities on critical thinking development and reported that group work encouraged collaborative problem-solving, perspective-taking, and cognitive flexibility. However, the study also noted that maintaining cognitive depth during group discussions could sometimes be challenging. (Fan et al., 2025) further explored collaborative writing and found that larger groups enhanced collective critical thinking, although conflicts and reduced individual participation occasionally limited effectiveness. These findings suggest that group work promotes critical thinking by exposing learners to diverse ideas and encouraging active interaction.

Studies on pair work also demonstrate its positive impact on critical thinking development. (Silva et al., 2022) showed that cooperative learning structures such as Think-Pair-Share were more effective than traditional teaching methods in improving critical thinking skills, including analysis, inference-making, and argumentation. Likewise, Shaharuddin et al. (2026) compared group work and pair work and found that both interaction types positively contributed to critical thinking development. However, pair work was viewed as more effective in reducing learner anxiety and ensuring equitable participation, while group work encouraged broader discussion and knowledge-sharing. Overall, past studies indicate that both group work and pair work are valuable for enhancing critical thinking, although pair work tends to provide deeper individual engagement while group work promotes wider collaboration and communication skills.

Conceptual Framework and Proposed Model of the Study

The conceptual framework for this study (Figure 1 below) is grounded in Social Constructivism by Vygotsky (1978), which emphasizes that knowledge is developed through social interaction and collaborative learning experiences. In the context of group work, students engage in discussions, negotiation of meaning, and shared problem-solving, all of which contribute to the development of critical thinking skills. This theory supports the idea that interaction among learners enhances higher-order thinking through exposure to multiple perspectives and peer scaffolding. The framework also incorporates Experiential Learning Theory by Kolb (2015), which explains that learning occurs through experience, reflection, and active experimentation. In group interactions, students collaboratively reflect on tasks and apply problem-solving strategies, thereby strengthening analytical and evaluative thinking. This perspective is further supported by Belbin (2014) whose study on team roles identifies thought-oriented (TO), action-oriented (AO), and people-oriented (PO) factors as essential elements

influencing teamwork effectiveness and problem-solving processes in collaborative settings.

The framework also explains critical thinking development in pair work through collaborative interaction and active engagement between two learners. Pair work encourages learners to exchange ideas, provide immediate feedback, and reflect on their reasoning in a more focused environment. This is aligned with the instrument developed by Baleghizadeh & Farhesh (2014) which emphasizes social interaction (SI), knowledge construction (KC), and social and cultural learning (SL) as key dimensions influencing collaborative learning and critical thinking. In pair interactions, learners actively construct knowledge through dialogue while benefiting from cultural and contextual understanding shared by peers. Furthermore, the framework is strengthened by Collaborative Learning Theory by Bruffee (1999), which highlights learning as a social process built through cooperation and shared understanding. This theory supports the group work component of the study and is linked to the work of Bateman et al. (2002), which identifies purpose and goals (PG), team relationships (TR), and skills and learning (SL) as significant factors contributing to effective group interaction and the enhancement of critical thinking skills. Together, these theories and constructs form the basis of the PLS-SEM framework used to compare critical thinking skills across group work and pair work contexts.

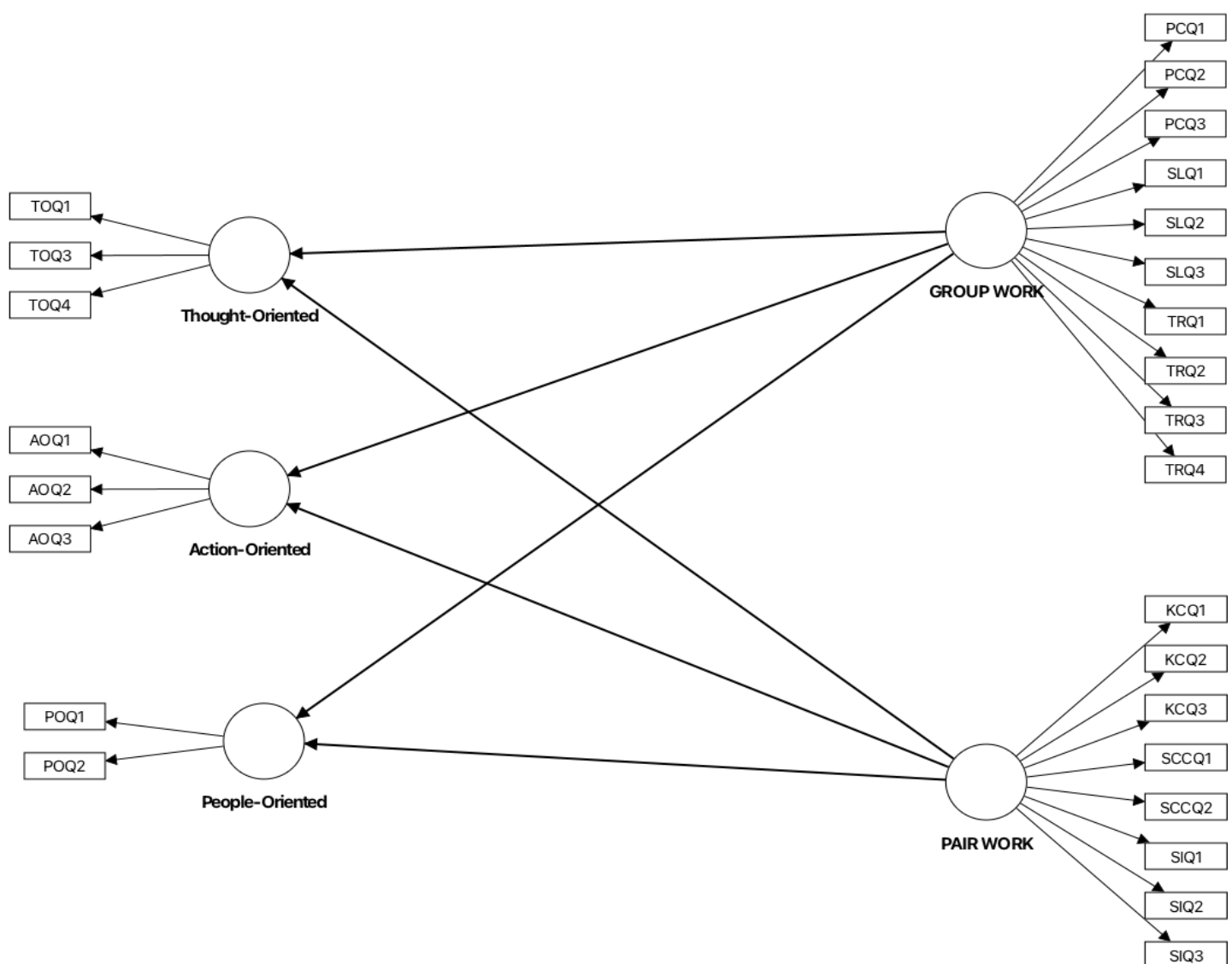


Figure 1- The Conceptual Framework

METHODOLOGY

Research Design

The research design for this study employs a quantitative approach using Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine and compare the relationships between group work, pair work, and

critical thinking skills. PLS-SEM is appropriate for this study because it enables the researcher to analyze multiple latent constructs simultaneously while assessing both measurement and structural models (Fornell & Bookstein, 1982). The conceptual framework presented in Figure 1 above consists of two main independent constructs: group work interaction and pair work interaction, which are linked to the dependent construct of critical thinking skills. Each construct is measured using several dimensions adapted from previous studies and represented as reflective indicators in the model. Hence, this section presents the (i) population and sample, (ii) instrument, and (iii) method of data collection and data analysis.

Population and Sample

Prior to the study, participants underwent a semester that involves pair work as well as group work. The demographic analysis of 232 respondents is presented in percentages. According to (Ziegenfuss et al., 2021) researchers report demographic data in percentages to establish sample representatives and allow for generalizability to a larger population. Presenting in percentages also provides an overview of participants' characteristics and offers a clear and understandable picture of the sample makeup

Table 2- Percentage for Demographic Profile

Question	Demographic Profile	Categories	Percentage (%)
1	Gender	Male	35%
		Female	65%
2	Cluster	Science & Technology	40%
		Social Sciences, Humanities & Business Management	60%

Table 2 above presents the demographic profile in percentages. For gender, 35% of the participants are male while 65% are female students.

Instrument

Table 3 presents the distribution of items included in the questionnaire. The instrument used a 5-point Likert scale, with scale 1 being Strongly Disagree. Scale 2 represents Disagree. Scale 3 represents Neutral, while scale 4 is Agree, and scale 5 is Strongly Agree.

Table 3- Distribution for Item in Instrument

SECTION	VARIABLE	CONSTRUCT	ITEM	
A	CRITICAL THINKING & PROBLEM SOLVING Belbin (2013)	Thought-Oriented	3	8
		Action-Oriented	3	
		People-Oriented	2	
B	GROUP WORK Bateman, et.al. (2002)	Purpose and Goals (PG)	1	8
		Team Relationships (TR)	4	
		Skills and Learning (SL)	3	
C	PAIR WORK Baleghizadeh & Farhesh (2014)	Social Interactions	3	8
		Knowledge Construction	3	
		Social & Cultural Context	2	
				24

Table 3 presents the distribution of items in the instrument used. This instrument is adapted from (Belbin, 2014), (Baleghizadeh & Farhesh, 2014); (Bateman et al., 2002) Section A has 8 items on critical thinking and problem-solving. Section B has 8 items on group work while Section C has 8 items on pair work.

Data Collection and Data Analysis

Data is collected via a Google Form. The data is then analyzed using SmartPLS 4 through two main stages. As suggested by (Hair, et.al. 2017), data analysis is done at two levels: the measurement and structural model. The

first stage is the measurement model, which measures the outer model. The second stage is the structural model, which measures the inner model. The analyzed data is used to answer the research questions and also to confirm the model chosen.

FINDINGS

The findings are presented in two stages. The first stage presents the (a) measurement model, and the third stage reveals the (b) structural model as well as answers research questions.

Measurement Model

In SmartPLS, the measurement model assesses the reliability and validity of the constructs. This is done by examining the relationships between them and their observable behavior. The measurement model measures the outer model. Figure 3 below shows the measurement model for this study. Further detailed explanation of this model is elaborated in the tables below. The measurement model assesses the instrument chosen. The results presented below are categorized into (i) reliability and (ii) validity (HTMT).

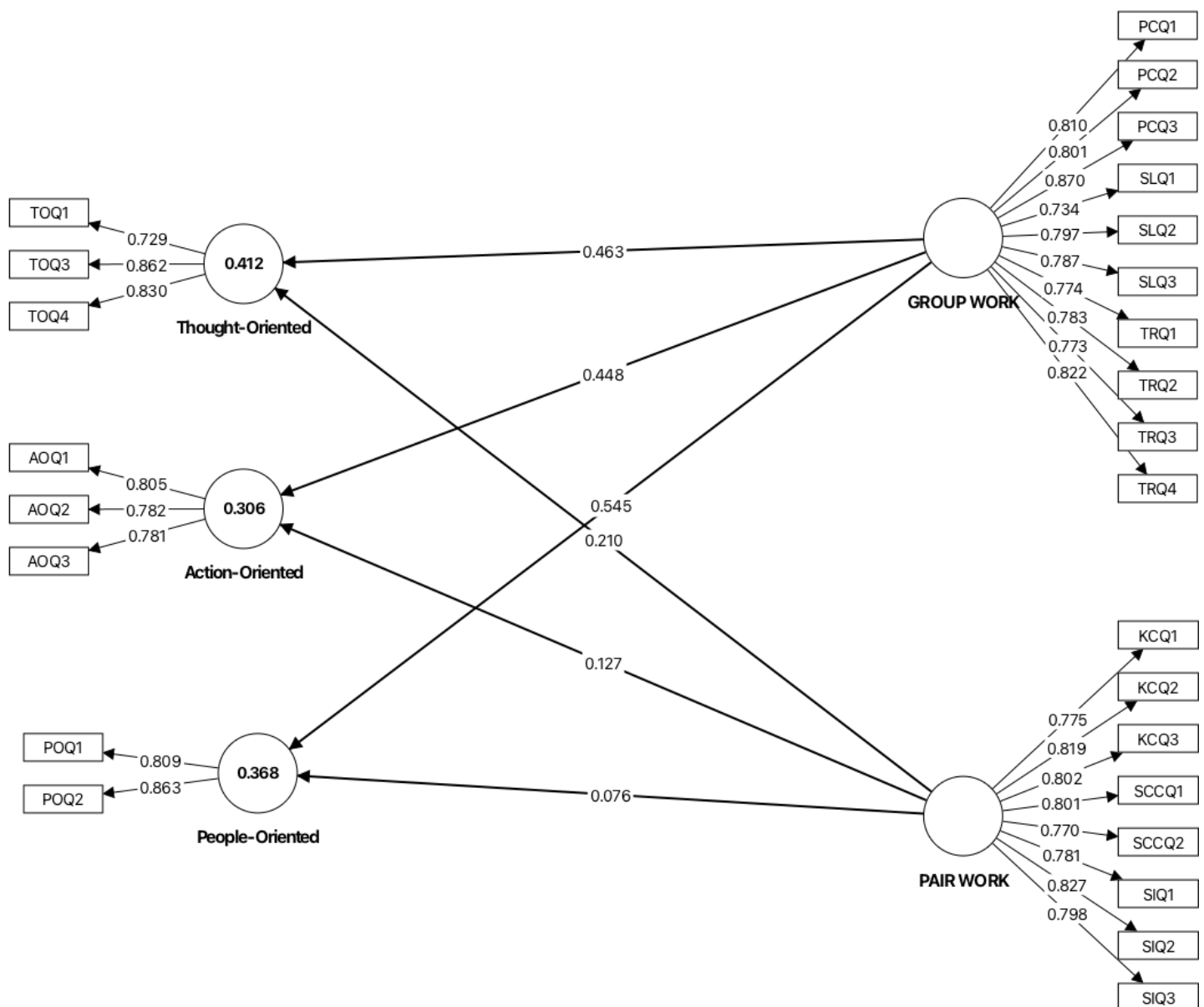


Figure 2- Measurement Model

Reliability

According to (Ringle & Sarstedt (2016)), reliability is assessed by checking indicator reliability and internal consistency reliability. Internal consistency is done using Composite reliability (ρ_c) and Cronbach's Alpha.

The cut-off value for Cronbach's Alpha is 0.70 to 0.90. The cut-off values for composite reliability (ρ_c) are 0.70-0.90. For indicator reliability, the factor loadings cut-off values are >0.70 and squared loadings ≥ 0.50 . Finally, the cut-off values for Average Variance Extracted (AVE) ≥ 0.50 .

Table 4 -Results for Reliability- Group Work

CONSTRUCT/ ITEM	FACTOR LOADING	CRONBACH'S ALPHA	COMPOSITE RELIABILITY (ρ_c)	AVERAGE VARIANCE EXTRACTED (AVE)
		0.935	0.945	0.633
PCQ1	0.81			
PCQ2	0.801			
PCQ3	0.87			

Table 4 presents the reliability results for Group Work. Factor loadings for all items ranged from 0.801 to 0.87. The loadings meet the indicator reliability threshold of 0.7. Next, the Cronbach's Alpha for Group Work is 0.935, the composite reliability is 0.945, and the AVE is 0.633.

Table 5-Results for Reliability- Pair Work

CONSTRUCT/ ITEM	FACTOR LOADING	CRONBACH'S ALPHA	COMPOSITE RELIABILITY (ρ_c)	AVERAGE VARIANCE EXTRACTED (AVE)
		0.918	0.933	0.635
KCQ1	0.775			
KCQ2	0.819			
KCQ3	0.802			

Table 5 presents the reliability results for the Pair Work. Factor loading of all items were found to be between 0.775 and 0.819. The loadings meet the indicator reliability threshold of 0.7. Next, the Cronbach's Alpha for Pair Work is 0.918, composite reliability is 0.933 and AVE is 0.635.

Table 6 -Results for Reliability- Thought-Oriented

CONSTRUCT/ ITEM	FACTOR LOADING	CRONBACH'S ALPHA	COMPOSITE RELIABILITY (ρ_c)	AVERAGE VARIANCE EXTRACTED (AVE)
		0.735	0.85	0.655
TOQ1	0.729			
TOQ3	0.862			
TOQ4	0.83			

Table 6 presents the reliability results for Thought-Oriented. Factor loading of all items were found to be between 0.729 and 0.862. The loadings comply with the indicator reliability of more than 0.7. Next, The Cronbach's Alpha for Thought-Oriented is 0.735, composite reliability is 0.85 and AVE is 0.655.

Table 7 -Results for Reliability- Action-Oriented

CONSTRUCT/ ITEM	FACTOR LOADING	CRONBACH'S ALPHA	COMPOSITE RELIABILITY (ρ_c)	AVERAGE VARIANCE EXTRACTED (AVE)
		0.698	0.832	0.623
AOQ1	0.805			
AOQ2	0.782			
AOQ3	0.781			

Table 7 presents the reliability results for the Action-Oriented. Factor loading of all items was found to be between 0.823 and 0.85. The loadings comply with the indicator reliability of more than 0.7. Next, the

Cronbach's Alpha for Action-Oriented is 0.698, the composite reliability is 0.832, and the AVE is 0.623.

Although the Cronbach's alpha value for Action-Oriented fell below the traditional 0.7 threshold, its Composite Reliability exceeds 0.6 (0.832), and the Average Variance Extracted is above 0.5 (0.623). According to Fornell & Larcker (1981), this satisfies the convergent validity and reliability requirements, as Cronbach's alpha tends to underestimate reliability in PLS-SEM and can be compensated for by adequate Composite Reliability.

Table 8 -Results for Reliability- People-Oriented

CONSTRUCT/ ITEM	FACTOR LOADING	CRONBACH' S ALPHA	COMPOSITE RELIABILITY (rho c)	AVERAGE VARIANCE EXTRACTED (AVE)
		0.573	0.823	0.7
POQ1	0.809			
POQ2	0.863			

Table 8 presents the reliability results for the People-Oriented. Factor loading of all items was found to be between 0.809 to 0.863. The loadings comply with the indicator reliability of more than 0.7. Next, the Cronbach's Alpha for People-Oriented is 0.573, the composite reliability is 0.823, and the AVE is 0.7.

Here, the Cronbach's alpha value for People-Oriented fell below the traditional 0.7 threshold, but its Composite Reliability exceeds 0.6 (0.823), and the Average Variance Extracted is above 0.5 (0.7). According to (Fornell & Larcker, 1981), this satisfies the convergent validity and reliability requirements, as Cronbach's alpha tends to underestimate reliability in PLS-SEM and can be compensated for by adequate Composite Reliability.

Validity

According to Ramayah et.al. (2018), for validity, the Discriminant validity (HTMT) needs to be <0.85 or <0.90.

Table 9- Discriminant Validity (HTMT)

	Action-Oriented	GROUP WORK	PAIR WORK	People-Oriented
GROUP WORK	0.671			
PAIR WORK	0.582	0.841		
People-Oriented	0.984	0.821	0.684	
Thought-Oriented	0.864	0.75	0.679	0.996

Table 9 presents the discriminant validity of the model. The HTMT for connectedness and autonomy is 0.889 and is therefore valid.

The HTMT for Group Work and Action Oriented is 0.671. The HTMT for Pair Work and Action-Oriented is 0.582, for Pair Work and Group Work is 0.841. Next, the HTMT for People-Oriented and Action-Oriented is 0.984, for People-Oriented and Group work is 0.821, and for People-Oriented and Pair Work is 0.684. Lastly, the HTMT for Thought-Oriented and Action-Oriented is 0.864, for Thought-Oriented and Group Work is 0.75, for Thought-Oriented and Pair Work is 0.679, and for Thought-Oriented and People-Oriented is 0.996. Two interactions (People-Oriented and Action-Oriented; Thought-Oriented and People-Oriented) did not meet the threshold <0.85 or <0.90. Nevertheless, (Franke & Sarstedt, 2019) suggested several procedures to test HTMT if it is >0.9. They state that if the value is lower than 1.0, the HTMT is still within the acceptable range.

Structural Model

In SmartPLS, the structural model visualizes the hypothesized causal relationships between constructs. The structural model is thus formed after the researcher has established the reliability and validity in the measurement model. For the analysis of the structural model, the researcher runs bootstrapping and examines the collinearity, path coefficients of determination, effect size, PLS predict, and IPMA. In addition to that, the analysis in the structural model allows the researcher to answer research questions 1-8 and hypotheses 1-8. Figure 3 below

shows the structural model for this study. Detailed explanation is elaborated in the tables below. The presentation of findings is classified into (i) collinearity, (ii) coefficients of determinants (R^2), (iii) p-value, (iv) effect size (f^2), (v) PLS Predict (Q^2), and (vi) IPMA.

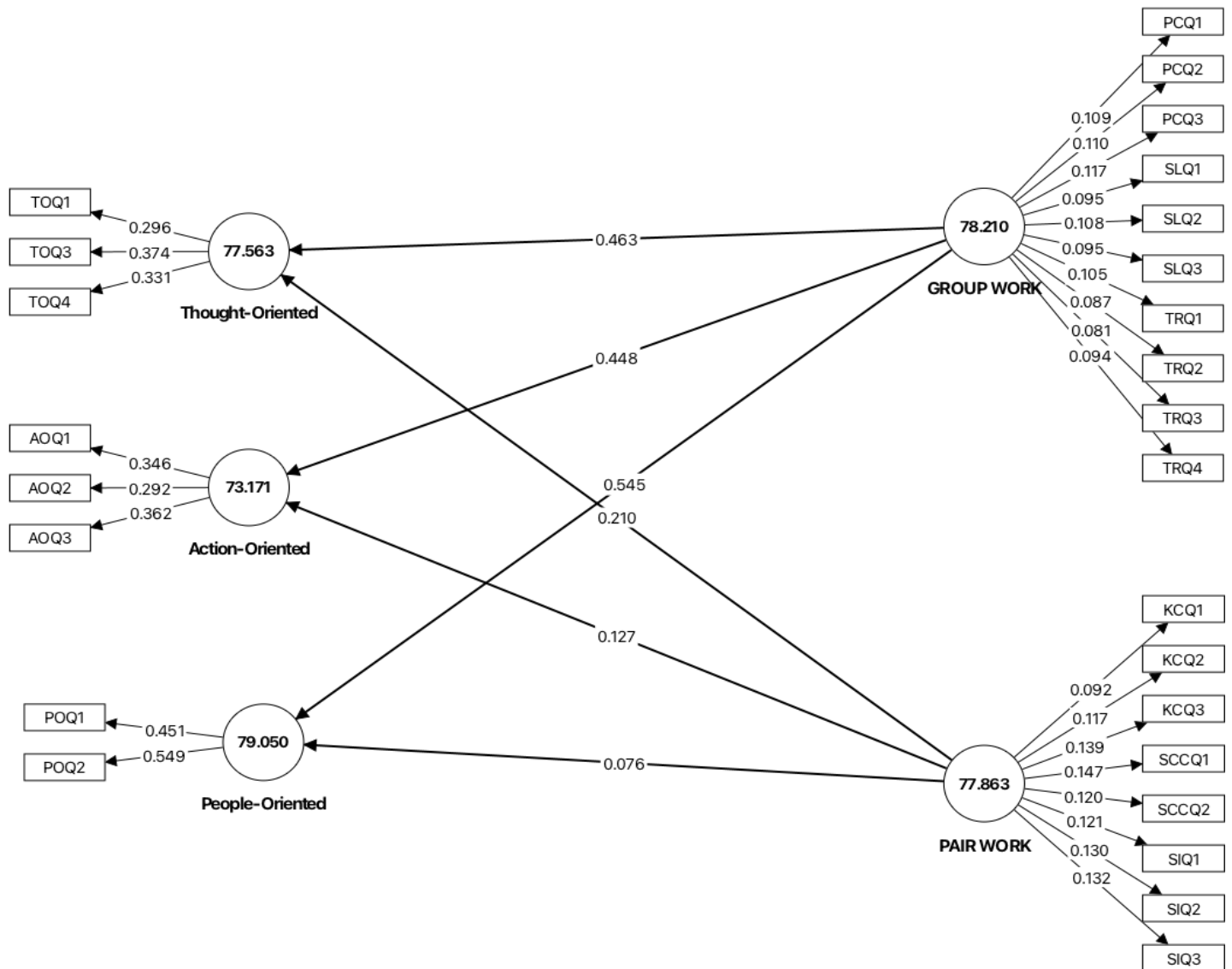


Figure 3- Structural Model

Collinearity

According to (Ramayah et al., 2018), the cut-off value for collinearity inner model VIF is ≤ 5.0 .

Table 10- Collinearity

	Original sample (O)
GROUP WORK -> Action-Oriented	2.594
GROUP WORK -> People-Oriented	2.594
GROUP WORK -> Thought-Oriented	2.594
PAIR WORK -> Action-Oriented	2.594
PAIR WORK -> People-Oriented	2.594
PAIR WORK -> Thought-Oriented	2.594

Table 10 above presents the collinearity results for this study. According to (Ringle & Sarstedt, 2016), the inner model VIF must be less than or equal to 5.0. All interactions met the threshold for Collinearity.

Coefficients of determination (R^2)

According to (Ramayah et al., 2018), for coefficients of determination (R^2) 0.2 to 0.7, depending on the field of study. Social Sciences & Economics follows the range above.

Table 11- R^2

	Original sample (O)
Action-Oriented	0.306
People-Oriented	0.368
Thought-Oriented	0.412

Table 11 shows the results for coefficients of determination (R^2). Results indicate that the R^2 for Action-Oriented 0.306 (31%), for People-Oriented is 0.368 (37%), and for Thought-Oriented is 0.412 (41%).

P-Value

Table 12- Interpretation for p-value

Thresholds	Interpretation	Decision
$p \leq 0.05$	Often considered statistically significant	Reject H_0
$p \leq 0.01$	Indicates very strong evidence against H_0	Reject H_0
$p > 0.05$	Weak or no evidence against H_0	Fai to reject H_0

According to (Goodman, 1999), a threshold of p-value is the cut-off for determining statistical significance, most set at 0.05. Below is the table that interprets the threshold.

Table 12 shows the interpretation for p=value. According to (Goodman, 1999), if the p-value is $p \leq 0.05$, the data is often considered statistically significant and the hull hypothesis is rejected. If it is $p \leq 0.01$, then it indicates very strong evidence to reject the null hypothesis (H_0). However, a $p > 0.05$ is considered weak an there is no evidence to reject the null hypothesis.

Table 13- Interpretation for p-value

Thresholds	Interpretation	Decision
$p \leq 0.05$	Often considered statistically significant	Reject H_0
$p \leq 0.01$	Indicates very strong evidence against H_0	Reject H_0
$p > 0.05$	Weak or no evidence against H_0	Fai to reject H_0

Table 14-Path Coefficient for the current study

	T statistics ($ O/STDEV $)	P values
GROUP WORK -> Thought-Oriented	4.475	0
GROUP WORK -> Action-Oriented	4.113	0
GROUP WORK -> People-Oriented	4.894	0
PAIR WORK -> Thought-Oriented	2.041	0.041
PAIR WORK -> Action-Oriented	1.392	0.164
PAIR WORK -> People-Oriented	0.78	0.436

Table 14 presents data to answer research questions and hypotheses. Path coefficients are presented in beta and t-value. The significant value (t-statistic) must be more than 1.65, and p-values must be less than 0.05 to show significant relationships.

Results in Table 14 reveal there are significance relationship for four interactions, but there were no significant relationships for two interactions. The p-value for GROUP WORK -> Thought-Oriented is $p=0$ ($t=4.475$); for

GROUP WORK -> Action-Oriented is $p=0$ ($t=4.113$); and for GROUP WORK -> People-Oriented is $p=0$ ($t=2.041$), and these interactions indicate significant relationships.

On the other hand, two interactions did not show significant relationships. The first is for PAIR WORK -> Action-Oriented with $p=0.164$ ($t=0.164$) and for PAIR WORK -> People-Oriented with $p=0.436$ ($t=0.78$)

Effect Size (f^2)

According to (Ramayah et al., 2018) the cutoff values for effect sizes (f^2) are 0.02 (small), 0.15 (medium), and 0.35 (large). This section presents data to answer research questions and hypotheses;

RQ5- Is there a significant effect for connectivism on diversity, openness, connectedness, and autonomy?

H₀₅- There is no significant effect for connectivism on diversity, openness, connectedness, and autonomy

According to (Ringle & Sarstedt, 2016), for effect size, values from 0.02 to 0.15 are considered small. Values between 0.15 to 0.35 are considered medium while values 0.35 and above are considered large.

Table 15- Effect Size

	Original sample (O)	Interpretation
GROUP WORK -> Thought-Oriented	0.141	small
GROUP WORK -> Action-Oriented	0.112	small
GROUP WORK -> People-Oriented	0.181	medium
PAIR WORK -> Thought-Oriented	0.029	medium

With reference to Table 15 above, the results indicate that there is a small effect size for GROUP WORK -> Thought-Oriented and GROUP WORK -> Action-Oriented. There is a medium effect size for GROUP WORK -> People-Oriented and PAIR WORK -> Thought-Oriented.

PLS Predict (Q^2)

In PLS-SEM, it is stated that Q^2 . Table 18 below reveals the PLS Predict (Q^2) for the dependent variable. The analysis reveals the Q^2 for all items in the dependent variable -connectedness.

Table 16- PLS Predict (Q^2)

	Q^2 predict	RMSE	MAE
Action-Oriented	0.284	0.858	0.658
People-Oriented	0.344	0.824	0.616
Thought-Oriented	0.388	0.794	0.593

Table 16 above shows the results for Q^2 Predict in the study. According to (Cohen, 1988), Q^2 Predict is used to interpret the magnitude of the predictive relevance. For $Q^2 > 0$ indicates the model has predictive relevance. Secondly, **0.02** indicates **small** predictive relevance. Next, **0.15** indicates **medium** predictive relevance. Finally, **0.35** indicates **large** predictive relevance.

Results for table 16 that all variables indicate predictive relevance. Specifically, Action-Oriented shows medium predictive relevance, People-Oriented has medium predictive relevance, while Thought-Oriented shows large predictive relevance.

IPMA

IPMA or Importance-Performance Matrix Analysis. According to (Ringle & Sarstedt, 2016), IPMA is used to evaluate the performance and importance of the chosen constructs or indicators within a model. In the context of this study, individual IPMA analysis was done on each construct and reported in Table 17 & 18.

Table 17- Total Effects for Importance

	Total effects
GROUP WORK -> Thought-Oriented	0.463
GROUP WORK -> Action-Oriented	0.448
GROUP WORK -> People-Oriented	0.545
PAIR WORK -> Thought-Oriented	0.21

Table 18- Latent Variables Average Performance (Performance)

	LV performance value, average
Action-Oriented	73.171
GROUP WORK	78.21
PAIR WORK	77.863
People-Oriented	79.05
Thought-Oriented	77.563

According to (Hauf, 2024) for PLS-SEM IPMA (Importance-Performance Map Analysis), there isn't a single "good score," but rather constructs with high importance (total effects) but low performance scores (rescaled 0-100) are key areas for improvement, indicating high potential for managerial action, while high importance/high performance is good, and low importance/low performance means less priority. Performance scores range 0-100, with higher values showing better attainment, but you interpret them *relative* to their importance.

Thought -Oriented

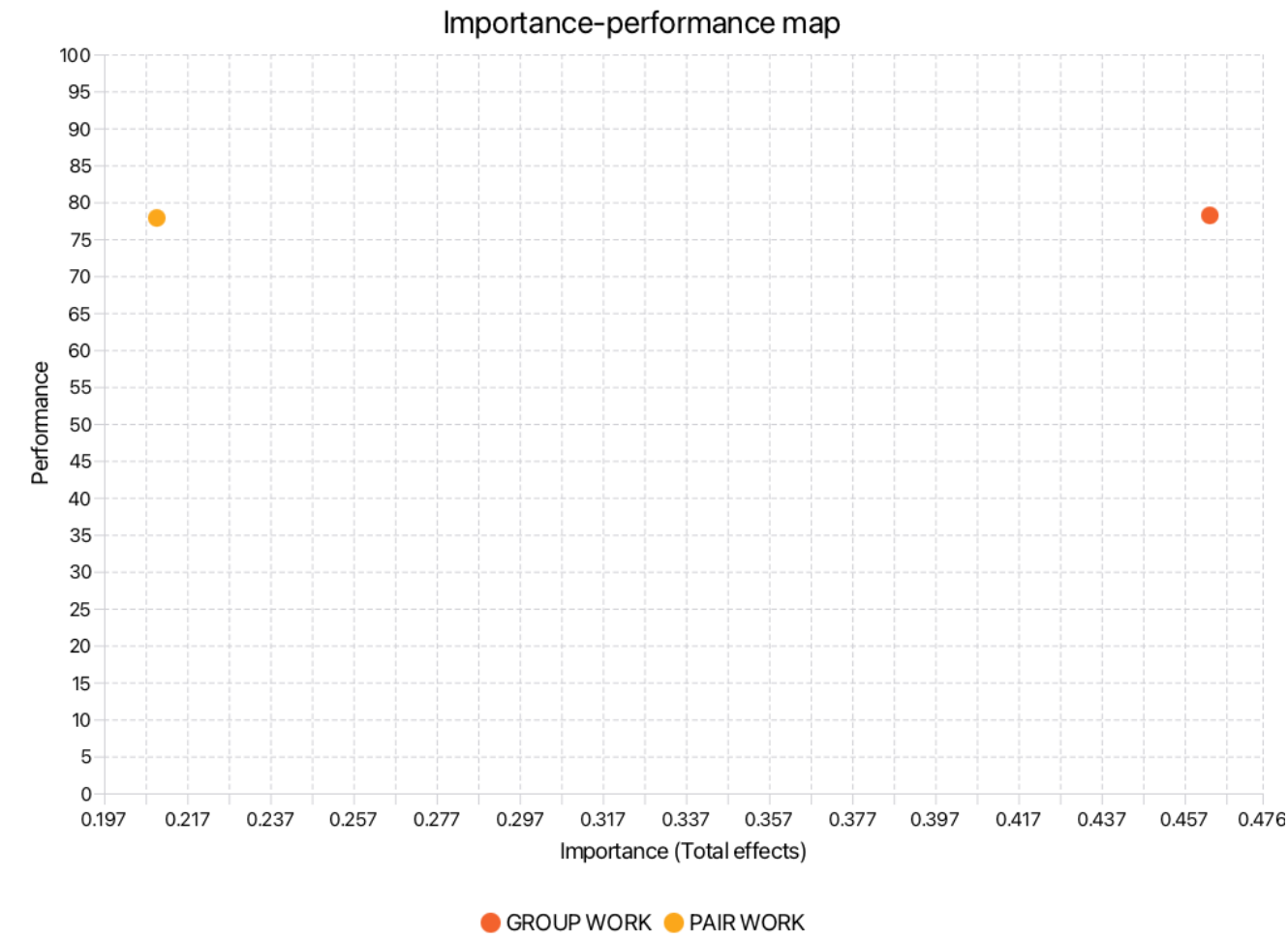


Figure 4- Importance-Performance Map for Thought -Oriented

Figure 4 above shows the importance and performance analysis for Thought -Oriented. When paired with Group Work, there is Moderate Importance/High Performance (Importance = 0.463; Performance = 78.21). When Thought -Oriented is paired with Pair Work, there is Low Importance/High Performance (Importance = 0.21; Performance = 77.863).

Action -Oriented



Figure 5- Importance-Performance Map for Action -Oriented

Figure 5 above shows the importance and performance analysis for Action -Oriented. When paired with Group Work, there is Moderate Importance/High Performance (Importance = 0.448; Performance = 78.21). When Action -Oriented is paired with Pair Work, there is Moderate Importance/High Performance (Importance = 0.448; Performance = 77.863).

People -Oriented

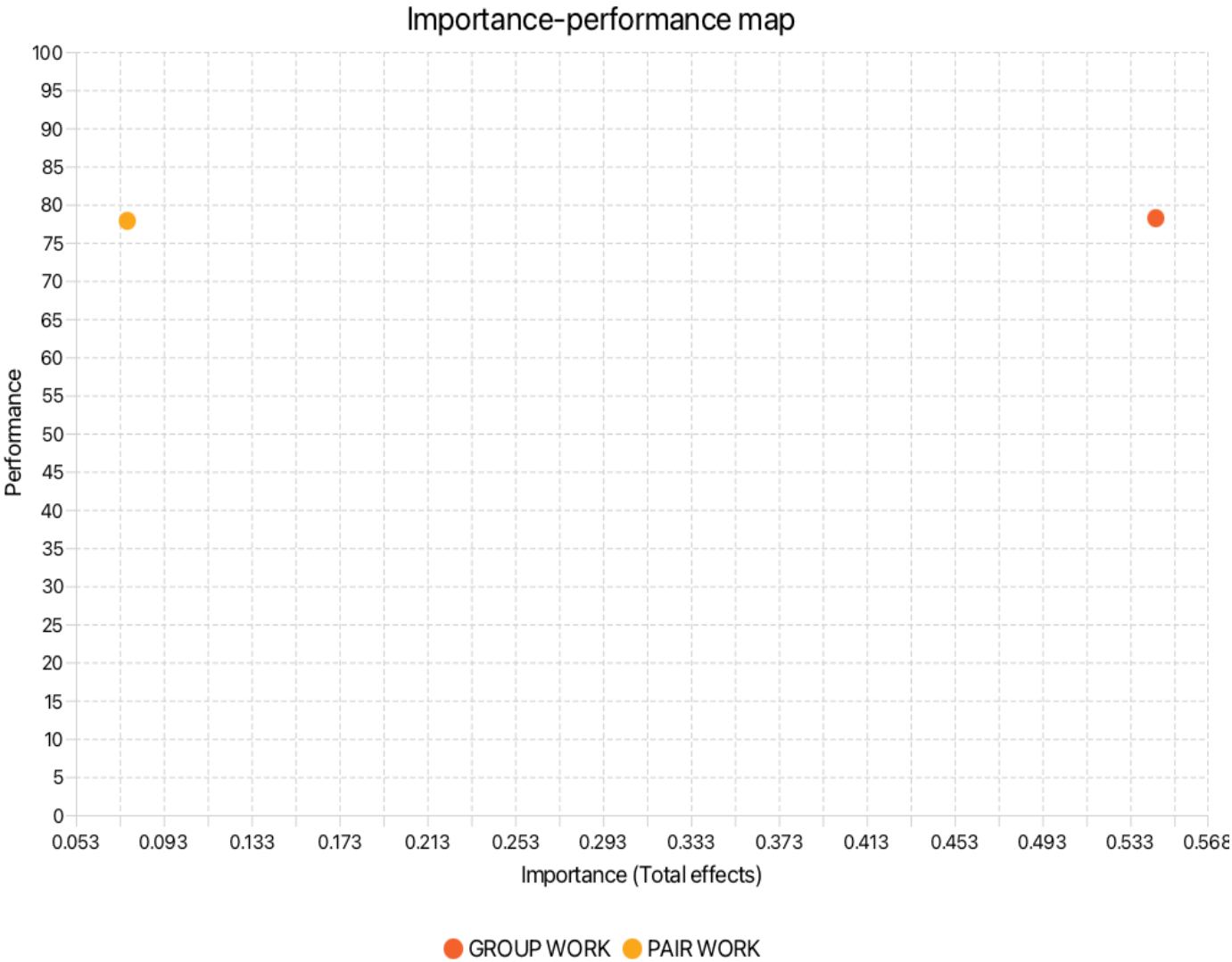


Figure 6- Importance-Performance Map for People -Oriented

Figure 6 above shows the importance and performance analysis for People -Oriented. When paired with Group Work, there is High Importance/High Performance (Importance = 0.545; Performance = 79.05).

CONCLUSION

Summary of Findings and Discussions

Table 19- Outcome of Research Hypothesis

NO	Research Question	Research Hypothesis	Outcome
1	Is there a significant relationship between Group work and Thought-Oriented Skills?	Ho1: There is no significant relationship between Group work and Thought-Oriented skills	Reject null hypothesis There is a relationship between Group work and Thought-Oriented Skills.
2	Is there a significant relationship between Group Work and Action-Oriented Skills?	Ho2: There is no significant relationship between Group Work and Action-Oriented Skills	Reject null hypothesis There is a relationship between Group Work and Action-Oriented Skills.

3	Is there a significant relationship between Group Work and People-Oriented Skills?	Ho3: There is no significant relationship between Group Work and People-Oriented Skills	Reject null hypothesis There is a relationship between Group Work and People-Oriented Skills.
4	Is there a significant relationship between Pair work and Thought-Oriented Skills?	Ho4: There is no significant relationship between Pair work and Thought-Oriented Skills	Reject null hypothesis There is a relationship between Pair work and Thought-Oriented Skills.
5	Is there a significant relationship between Pair work and Action-Oriented Skills?	Ho5: There is no significant relationship between Pair work and Action-Oriented Skills	Accept null hypothesis. There is no significant relationship between Pair work and Action-Oriented Skills
6	Is there significant effect between Pair Work and People-Oriented Skills	Ho6: There is no significant between Pair Work and People-Oriented Skills	Accept null hypothesis. There is no significant between Pair Work and People-Oriented Skills
7	Is there is a significant effect between Group Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Ho7: There is no significant effect between Group Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Null hypothesis rejected for all the interactions of Group Work & Thought-Oriented, Action-Oriented and People-Oriented.
			GROUP WORK -> Thought-Oriented (small)
			GROUP WORK -> Action-Oriented (small)
8	Is there is a significant effect between Pair Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	Ho8: There is no significant effect between Pair Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People Oriented Skills)	GROUP WORK -> People-Oriented(medium)
			Null Hypothesis rejected for Pair work and Thought-Oriented. There is a significant effect for Pair Work and Thought- Oriented. PAIR WORK -> Thought-Oriented (medium)
			Null Hypothesis accepted for Pair work and Action and People Oriented. There is no significant effect for Pair work and Action and People Oriented

Table 14 above shows the presentation of the outcome of the research questions and hypotheses.

The null hypotheses are accepted for the research hypotheses 5, 6 and part of 8, which means that there were no significant relationships between Pair work and Action-Oriented Skills, Pair Work and People-Oriented Skills, and there are no significant effects for Pair work and Action and People Oriented.

The null hypotheses are rejected for research hypotheses 1,2,3,4, 7 and partly 8. There are significant relationships for Group work and Thought-Oriented (H₀1), Group work and Action-Oriented (H₀2), Group work and People-Oriented (H₀3), Pair work and Thought-Oriented Skills (H₀4). In addition to that, there were significant effects for Group Work and Critical Thinking Skills (Though-Oriented, Action-Oriented & People-Oriented Skills)- H₀7, and also significant effects for Pair Work and Though- Oriented.

This study examined the comparison of critical thinking skills across group work and pair work using a PLS-SEM analysis framework. The findings revealed that group work had significant relationships with thought-oriented, action-oriented, and people-oriented critical thinking skills, while pair work showed a significant relationship only with thought-oriented skills. The results further demonstrated that group work had stronger effects on critical thinking development compared to pair work, particularly in promoting collaboration,

communication, and problem-solving abilities. These findings support previous studies by Dias-Oliveira et al. (2024), who reported that collaborative learning activities improved critical thinking, teamwork, and communication skills, as well as Gayle and Roque (2024), who found that group activities encouraged collaborative problem-solving and perspective-taking. The findings also align with Silva et al. (2022), which highlighted the effectiveness of cooperative learning approaches in enhancing critical thinking skills.

Implications and Suggestions for Future Research

Figure 4 below presents the proposed model for critical thinking in group work and pair work. Group work is found to encourage thought-oriented, action-oriented, and people-oriented skills. However, pair work only supports thought-oriented skills.

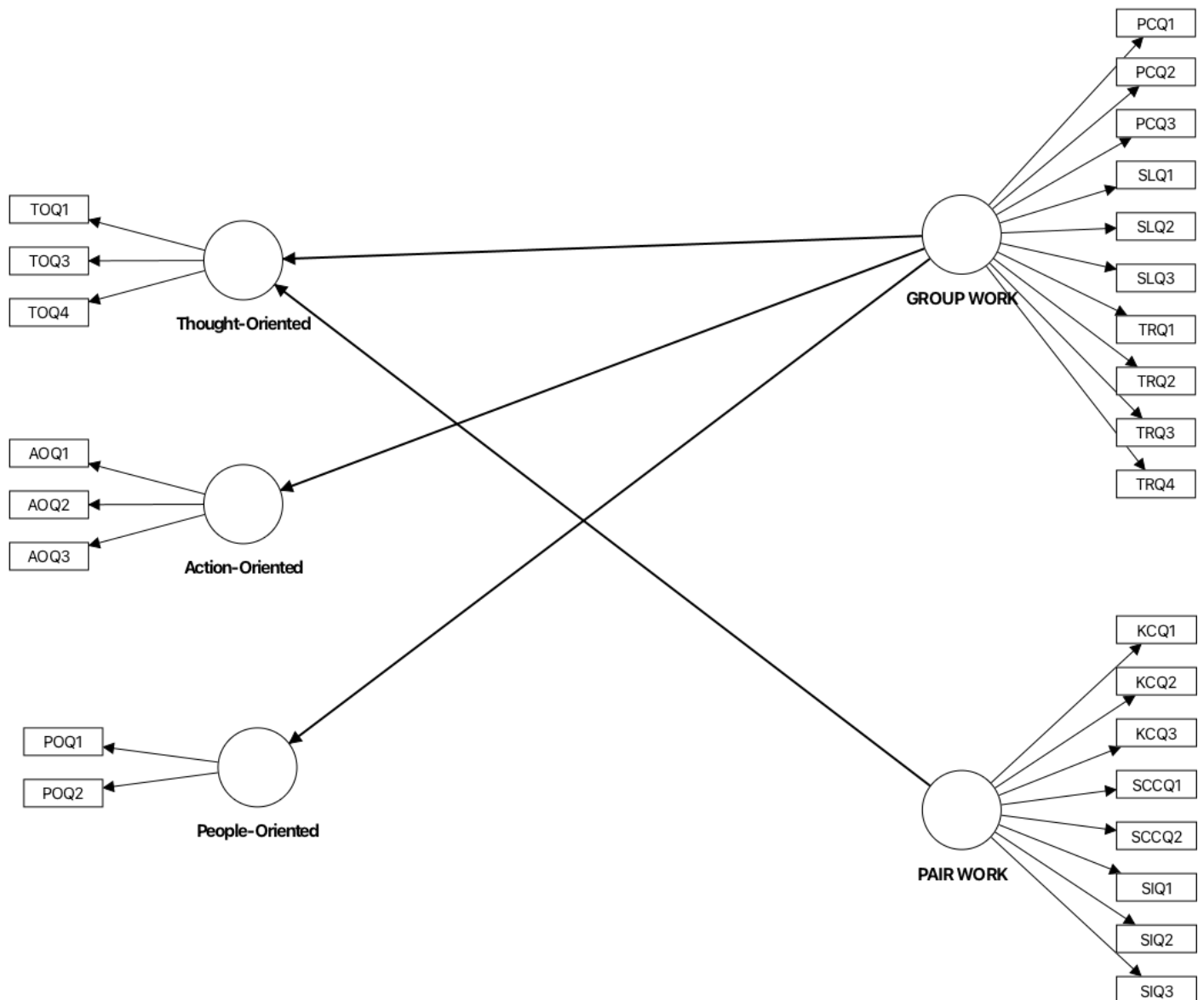


Figure 4- The Proposed Model

The study has several important implications for educational practice. First, the findings suggest that educators should incorporate more collaborative learning activities, particularly structured group work, to strengthen students' critical thinking skills. Group work was found to contribute significantly to thought-oriented, action-oriented, and people-oriented dimensions, indicating its effectiveness in promoting analytical thinking, teamwork, and communication.

Pair work, however, remains useful for encouraging reflective thinking and focused interaction, especially in tasks requiring deeper individual engagement. The use of PLS-SEM also demonstrated the value of examining

multiple constructs simultaneously to better understand the relationships between collaborative learning and critical thinking development.

For future research, researchers may expand the study by involving larger and more diverse samples from different educational institutions and disciplines. Future studies could also employ mixed method approaches to gain deeper insights into students' interaction experiences during group and pair work activities. Additionally, future research may explore other variables such as motivation, communication anxiety, or academic performance to further explain how collaborative learning environments influence critical thinking skills. Future studies should include qualitative methods, such as interviews or classroom observations, to explain how group work and pair work influence critical thinking development.

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APPENDIX

Critical Thinking & Problem Solving With Group Work Vs Pair Work

(this instrument is adapted from Baleghizadeh & Farhesh ,2014); Belbin ,2013) ; Batemen,et.al.,2002)

SECTION	VARIABLE	CONSTRUCT	ITEM	
A	CRITICAL THINKING & PROBLEM SOLVING Belbin (2013)	Thought-Oriented	3	8
		Action-Oriented	3	
		People-Oriented	2	
B	GROUP WORK Bateman, et.al. (2002)	Purpose and Goals (PG)	1	8
		Team Relationships (TR)	4	
		Skills and Learning (SL)	3	
C	PAIR WORK Baleghizadeh & Farhesh (2014)	Social Interactions	3	8
		Knowledge Construction	3	
		Social & Cultural Context	2	
				24

Section B-Critical Thinking and Problem-Solving Skills

Thought-Oriented (TO)

ITEM	1	2	3	4	5
TOQ1 When suddenly asked to consider a new project, I am able to take an independent and innovative look at most situations.					
TOQ3 When trying to solve a complex problem, I like to weigh up and evaluate a range of suggestions thoroughly before choosing.					
TOQ4 When suddenly asked to consider a new project, I approach the problem in a carefully analytical way					

Action-Oriented (AO)

ITEM	1	2	3	4	5
AOQ1 In seeking satisfaction through my work, I tend to have a creative approach to solve problem solving.					
AOQ2 In carrying out my day-to-day work, I tend to see pattern in solving problems where others would see items as unconnected.					
AOQ3 I take considerable amount of time to make judgement but most often, the judgement made is accurate.					

People-Oriented (PO)

ITEM	1	2	3	4	5
POQ1 I can see how ideas and techniques can be used in perceiving new relationships.					
POQ2 I analyse other people's ideas objectively, by evaluating both advantages and disadvantages					

Section C- Group Work

Purpose and Goals (PG)

ITEM	1	2	3	4	5
PGQ3 We set and meet challenging goals.					

Team Relationships (TR)

ITEM	1	2	3	4	5
TRQ1 Team members appreciate one another's unique capabilities.					
TRQ2 Team members are effective listeners.					
TRQ3 Communication in our group is open and honest.					
TRQ4 Members of our team trust each other.					

Skills and Learning (SL)

ITEM	1	2	3	4	5
SLQ1 We have the skills we need to do our jobs effectively.					
SLQ2 We view everything, even mistakes, as opportunities for learning and growth					
SLQ3 Team members embrace continuous improvement as a way of life.					

Section D- Pair Work

Social Interaction (SI)

ITEM	1	2	3	4	5
SIQ1I like learning activities in which students work together in pairs					
SIQ2 Pair work create a relaxing learning environment.					
SIQ3 Students give more help to each other during pair work					

Knowledge Construction (KC)

ITEM	1	2	3	4	5
KCQ1 Pair work help students solve tasks better and faster.					
KCQ2 Pair work help students more chances to exchange ideas with each other.					
KCQ3 Pair work help students understand information better after explaining it to others.					

Social and cultural context (SCC)

ITEM	1	2	3	4	5
SCCQ1 Students learn more about how to share the responsibilities when working in pairs					
SCCQ2 I feel more accepted by others after working within a pair					